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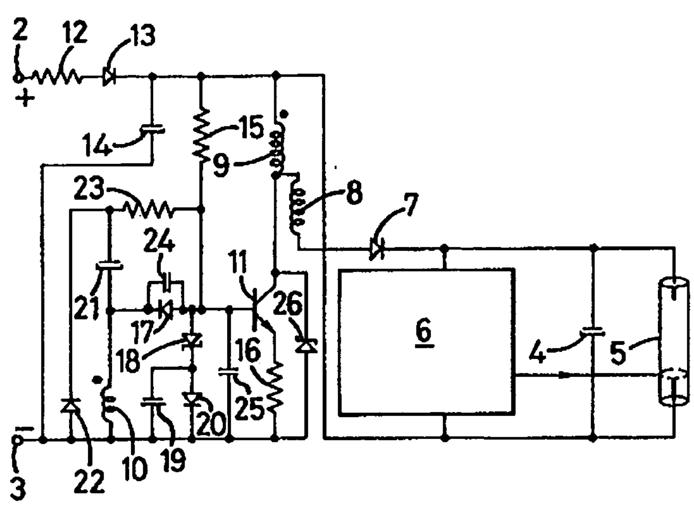

(57) Abstract

A capacitor (4), which discharges into a xenon tube (5) that is triggered recurrently by a pulse generator (6), is charged incrementally between triggering, from flyback current within primary and secondary windings (9, 8) of a transformer of the inverter circuit (1). The primary winding (9) is the collector load of a transistor (11) that switches between conduction and non-conduction in dependence upon feedback via a tertiary winding (10) of the transformer. The voltage applied to the base-emitter circuit of the transistor (11) is limited by a Zener diode (18) connected in series with a shunt-connected capacitor (19) and diode (20). The diode (18) conducts in the reverse direction during flyback voltage induced in the winding (10) to discharge the capacitor (19) incrementally for stabilizing the charged voltage of the load capacitor (4) against variation of input DC. A DC-restoration circuit (21-23) supplies base current to the transistor (11) from the tertiary winding (10), and capacitors (24, 25) provide further circuit stabilisation.

Inverter Circuits

This invention relates to inverter circuits.

Inverter circuits for converting DC input voltage to higher-voltage output to charge a capacitive load, are known and find application, for example, in the powering of xenon flash-discharge tubes. Xenon flash-discharge tubes are used to produce repetitive short-duration flashes of light for beacon purposes in giving a visual signal or warning, and in this respect may be used in burglar- and fire-alarm systems and on police, ambulance, fire-service and other vehicles.

In many applications and potential applications of xenon tubes in this way, the voltage of the available DC power supply may have any of a number of nominal values, and in any particular case may be liable to vary significantly from that nominal value. For example, the beacon may be for use on a vehicle having a 12-volt, 24-volt or other battery, and the battery-voltage may vary significantly from the nominal value according to the state of charge of the battery and whether the vehicle's engine is running. It is not in general simple using known inverter circuits to provide for satisfactory operation of xenon tubes in these circumstances, since the output of the inverter is too dependent on the power-supply voltage and the majority of xenon tubes operate satisfactorily only within a narrow range of applied voltage.

It is an object of the present invention to provide a form of inverter circuit that may be used in the above circumstances to power a xenon tube satisfactorily throughout a wide range of DC supply voltage.

According to the present invention there is provided an inverter circuit for charging a capacitive load, in which switching means having a control input is connected in series with inductance across DC-input terminals of the circuit to switch from a conductive to a non-conductive state recurrently for charging the capacitive load incrementally from flyback in the inductance, the switching means being switched from its conductive to non-conductive state in accordance with voltage that is applied to its control input and is dependent upon the current flow in the serially-connected inductance and switching mean, characterised in that said voltage is limited according to a threshold value that is reduced incrementally in dependence upon charging of the capacitive load such as to tend to stabilise the charged voltage of the capacitive load against variation with variation of the DC input voltage.

The switching means may be a transistor with the inductance connected in its collector circuit and having resistance connected in its emitter circuit.

The inductance may be a winding of a transformer, and in this case said voltage applied to the control input of the switching means may be dependent upon feedback via another winding of the transformer.

The voltage applied to the control input may be limited by a Zener diode which is connected in series with capacitance and which conducts in its forward direction to charge the capacitance when the threshold value is exceeded. In this case, the capacitance may be discharged incrementally via the Zener diode conducting in its reverse direction during the non-conductive state of the switching means, in dependence upon the charge of the capacitive load over a certain limit voltage.

A xenon flashing-beacon unit incorporating an inverter circuit according to the present invention, will now be described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a schematic representation of the xenon flashing-beacon unit showing the inverter circuit according to the invention;

Figure 2 is illustrative of voltage excursions across components of the inverter circuit of Figure 1; and

Figure 3 is a schematic representation of the xenon flashing-beacon unit incorporating modification of the inverter circuit according the invention.

Referring to Figure 1, the xenon flashing-beacon unit includes an inverter circuit 1 that is powered by an external DC-supply source (not shown) connected to input terminals 2 and 3, for charging a capacitor 4 to a higher voltage incrementally. The voltage across the capacitor 4 is applied between the anode and cathode of a xenon tube 5 of the unit, and a trigger-pulse generator 6 within the unit, supplies a high-voltage pulse at regular intervals between the trigger-electrode and cathode of the tube 5. The trigger-pulse initiates discharge within the tube 5 of the accumulated charge of the capacitor 4, and the process of charging the capacitor 4 incrementally and then discharging it through the tube 5, recurs to cause the emission of a regular succession of bright flashes of light from the tube 5.

The capacitor 4 is charged via a diode 7 from a secondary winding 8 of a transformer which has a primary winding 9 and a tertiary, feedback winding 10. The secondary winding 8 is connected to the diode 7 from the collector electrode of a transistor 11 that is supplied with

collector current from the positive supply terminal 2 via a resistor 12, a diode 13 and the primary winding 9 in series. The diode 13 provides protection against reverse connection of the power-supply and in conjunction with the resistor 12 and a capacitor 14 that is connected between the diode 13 and the negative supply terminal 3, provides filtering of the power input to the unit.

Connection of a DC-supply source to the terminals 2 and 3, causes the transistor 11 to conduct with base-current flowing from the resistor 12 and diode 13 via a resistor 15. The collector-current flow in the primary winding 9 increases linearly from zero at a rate approaching E/L, where E is the supply voltage and L is the primary inductance of the winding 9. This increasing current causes the voltage across an emitter-load resistor 16 to increase progressively towards equality with the voltage induced from the primary winding 9 across the feedback winding 10.

The winding 10 is connected in series with a diode 17 between the base electrode of the transistor 11 and the terminal 3 so that when the voltage across the resistor 16 has risen sufficiently, the diode 17 conducts. This diverts current flowing through the resistor 15 away from the base of the transistor 11 to flow through the winding 10, and so switches the transistor 11 off.

The voltage waveforms across the emitter-load resistor 16 and the feedback winding 10 are illustrated in Figure 2 in continuous line W and chain-dotted line X, respectively, for successive cycles of conduction and non-conduction of the transistor 11. At the instant when the transistor 11 switches off (indicated as point A on the time-axis of Figure 2), the energy stored in the primary winding 9 is equal to $\frac{1}{2}LI^2$, where L is the effective inductance and I is the current flowing through

it at that time. Substantially all of this energy is transferred to the capacitor 4 via the diode 22 by the consequent backswing or flyback current induced in the winding 8.

Following transfer of the charge energy from the winding 8 to the capacitor 4, the transistor 11 switches on again (indicated as point B on the time-axis of Figure 2). The current flow through the transistor 11 increases progressively as determined by the inductance of the winding 9, until the voltage across the emitter-load resistor 16 has risen sufficiently in relation to the voltage induced in the feedback winding 10, to switch the transistor 11 off and transfer further charge to the capacitor 4. This cycle of switching on and off of the transistor 11 with incremental charging of the capacitor 4 is repeated throughout the intervals between the trigger pulses from the generator 6. Energy is accordingly built up progressively within the capacitor 4 during these intervals for periodic discharge into the xenon tube 5.

To the extent that the inverter circuit 1 has so far been described, it suffers from the disadvantage that its output, which in the present instance is used to charge the capacitor 4, is dependent on the supply voltage. In this regard, the voltage across the feedback winding 10 is related to the supply voltage, being approximately E/N, where N is the ratio of the turns of the primary winding 9 to those of the winding 10, so that increase of supply voltage leads to increase in the magnitude I of collector-current flowing in the winding 9 before the voltage across the resistor 16 has risen sufficiently to switch the transistor 11 off. Such an increase leads to an increase in the energy transferred to the capacitor 4 from induced flyback in the winding 8.

The above disadvantage is overcome according to the present invention in the inverter circuit of Figure 1 by connecting a Zener diode 18 in series with a shunt-connected capacitor 19 and diode 20, across the series-connected diode 17 and winding 10. The diodes 18 and 20 are chosen in relation to the ratio N such that throughout part, or all, of the range of supply-voltage variation to be covered, the sum of their diode-drop voltages (the voltages across the diodes on forward conduction) is less than the sum of the feedback voltage induced across the winding 10 and the voltage drop across the diode 17.

With the circuit according to the present invention, the transistor 11 switches off when the voltage across the resistor 16 reaches whichever is the lower of: (a) the magnitude of the voltage across the serially-connected diode 17 and feedback winding 10 less the base-bias voltage of the transistor 11, and (b) the sum of the diode-drop voltages of the diodes 18 and 20 less the base-bias voltage of the transistor 11. The magnitude I of the peak current in the winding 9 is accordingly limited, and this, as well as being of advantage in limiting the energy in consequence transferred to the capacitor 4 on each flyback at higher supply voltages, simplifies the choice of a transistor 11 to cover the operating range of the flashing-beacon unit.

Even though the peak magnitude I of current in the winding 9 is limited by the diodes 18 and 20 during the initial phase of operation when the transistor 11 is conductive, the rate at which this current, and therefore the voltage across the resistor 16, rises is still dependent upon the supply voltage, increasing the operating frequency of the inverter circuit 1. Accordingly, if the charging operation were limited by the diodes 18 and 20 alone, there would still be the

disadvantageous effect that the frequency of transfer of energy to the capacitor 4 would increase with increase in supply-voltage within the operating range. This effect is counteracted in the circuit of Figure 1 by utilising the Zener-breakdown characteristic of the diode 18 to lead to discharge of the capacitor 19 incrementally..

Operation of the inverter circuit 1 in the latter respect is related to the increase which takes place in the amplitude of the flyback pulse across the windings 9 and 8, as the capacitor 4 is progressively charged. The pulse at the feedback winding 10 is negative during the flyback phase and is of an amplitude V/M, where V is the instantaneous voltage across the capacitor 4, and M is the ratio of the total number of turns of the primary and secondary windings 9 and 8 together, to the number of turns of the feedback winding 10. When V/M exceeds the Zener-breakdown voltage of the diode 18, the diode 18 becomes conductive in its reverse direction to drive the potential of the junction of capacitor 19 with the diode 20, in the negative sense. The charge of the capacitor 19 is in this way sufficiently reduced over a number of cycles of operation of the inverter circuit 1, to divert current supplied to the base of the transistor 11 via the resistor 15, to flow instead to the capacitor 19 via the diode 18. This is effective to stop operation of the inverter circuit 1 until the capacitor 4 is discharged, and to stabilise the voltage across the capacitor 4 in its charged state, to a value near (M x Z) where Z is the Zener-breakdown voltage of the diode 18.

The circuit of Figure 1 would function without the diode 20. The diode 20, however, limits the maximum current drawn by the transistor 11 at higher supply voltages and allows the transistor 11 to have a lower specification than otherwise might be required.

If the ratio of the maximum to minimum voltage in the range of operational supply-voltages to be covered, is as wide as 10:1, the power rating required of the base-bias resistor 15 can be excessively high. The resistor 15 must provide enough current at the lowest supply voltage to drive the transistor 11, but at ten times this voltage the power dissipation in the resistor 15 will be increased by a factor of about 100. This problem can be avoided by adopting a modification of the circuit of Figure 1, shown in Figure 3 and based on recognition that in practice the peak-to-peak feedback pulse in winding 10 has a smaller amplitude range than 10:1. There is a smaller amplitude range of feedback pulse because the voltage excursion across the output of the circuit 1 at the capacitor 4 is typically within a factor of 3 from maximum to minimum.

As shown in Figure 3, the modification involves the addition of a capacitor 21 and a diode 22 for supplying the positive-going feedback pulse induced in the winding 10 to the base electrode of the transistor 11 via a resistor 23, with DC-restoration. The supply of base current from the winding 10 in this way saves on the power requirement of the circuit 1, the function of the resistor 15 in this context being solely to provide a small current to start operation of the inverter circuit. The resistor 15 can therefore have a high value so as to dissipate little heat.

A small degree of variation of the output voltage across the capacitor 4 in its charged state, with variation of the power-supply voltage, may still arise in the circuit of Figure 3 as so far described. For example, rise in the power-supply voltage increases the magnitude of current that is required to flow through the Zener diode 18 before inverter operation is stopped, so that the voltage across the diode 18, and therefore the resultant

peak output voltage across the capacitor 4, is higher. A capacitor 24 is however connected in shunt with the diode 17 to counteract this effect. With the capacitor 24 connected in this way, discharge of the capacitor 19 increases with increase in the negative excursion of the voltage waveform induced in the winding 10, so as effectively to balance out increase in voltage across the diode 18 when the supply-voltage rises.

A capacitor 25 in connected in shunt with the series-connected diodes 18 and 20, to stabilise the circuit against spurious oscillation, and a Zener diode 26 is connected between the collector electrode of the transistor 11 and the terminal 3 to protect the transistor 11 against overshoots arising in stray inductance.

Claims:

1. An inverter circuit for charging a capacitive load, in which switching means having a control input is connected in series with inductance across DC-input terminals of the circuit to switch from a conductive to a non-conductive state recurrently for charging the capacitive load incrementally from flyback in the inductance, the switching means being switched from its conductive to non-conductive state in accordance with voltage that is applied to its control input and is dependent upon the current flow in the serially-connected inductance and switching mean, characterised in that said voltage is limited according to a threshold value that is reduced incrementally in dependence upon charging of the capacitive load such as to tend to stabilise the charged voltage of the capacitive load against variation with variation of the DC input voltage.

2. An inverter circuit according to Claim 1 wherein the switching means is a transistor with the inductance connected in its collector circuit and having resistance connected in its emitter circuit.

3. An inverter circuit according to Claim 1 or Claim 2 wherein the inductance is a winding of a transformer and said voltage is dependent upon feedback via another winding of the transformer.

4. An inverter circuit according to any one of Claims 1 to 3 wherein said voltage is limited by a Zener diode which is connected in series with capacitance and which conducts in its forward direction to charge said capacitance when the threshold value is exceeded, and said capacitance is discharged incrementally via the

Zener diode conducting in its reverse direction during the non-conductive state of the switching means in dependence upon the capacitive-load charge.

5. An inverter circuit according to Claim 4 wherein a diode is connected in shunt with said capacitance.

6. An inverter circuit according to Claim 2 wherein said voltage is dependent upon voltage induced in a winding which is inductively linked with said inductance and which is connected via a diode to the base of the transistor, a Zener diode is connected in series with capacitance to the base of the transistor in shunt with the series-connected winding and first-mentioned diode such that the Zener diode conducts in its forward direction when the threshold value is exceeded during the conductive state of the transistor, and conducts in its reverse direction via said first-mentioned diode to discharge said capacitance incrementally in dependence upon voltage induced in the winding from flyback in the inductance.

7. An inverter circuit according to Claim 6 wherein a DC-restoration circuit connected to the winding supplies base current to the transistor.

8. An inverter circuit according to Claim 6 or Claim 7 wherein a capacitor is connected in shunt with said first-mentioned diode.

9. An inverter circuit according to any one of Claims 6 to 8 wherein a further diode shunts said capacitance to limit the maximum current drawn by the transistor.

10. An inverter circuit according to any one of Claims 1 to 9 connected to a capacitive load for recurrent re-charging of the load.

11. An inverter circuit according to Claim 10 wherein the capacitive load is arranged for recurrent discharge into a xenon flash-discharge tube.

12. A xenon-flashing beacon unit including an inverter circuit according to any one of Claims 1 to 9 for powering the xenon flash-discharge tube of the unit.

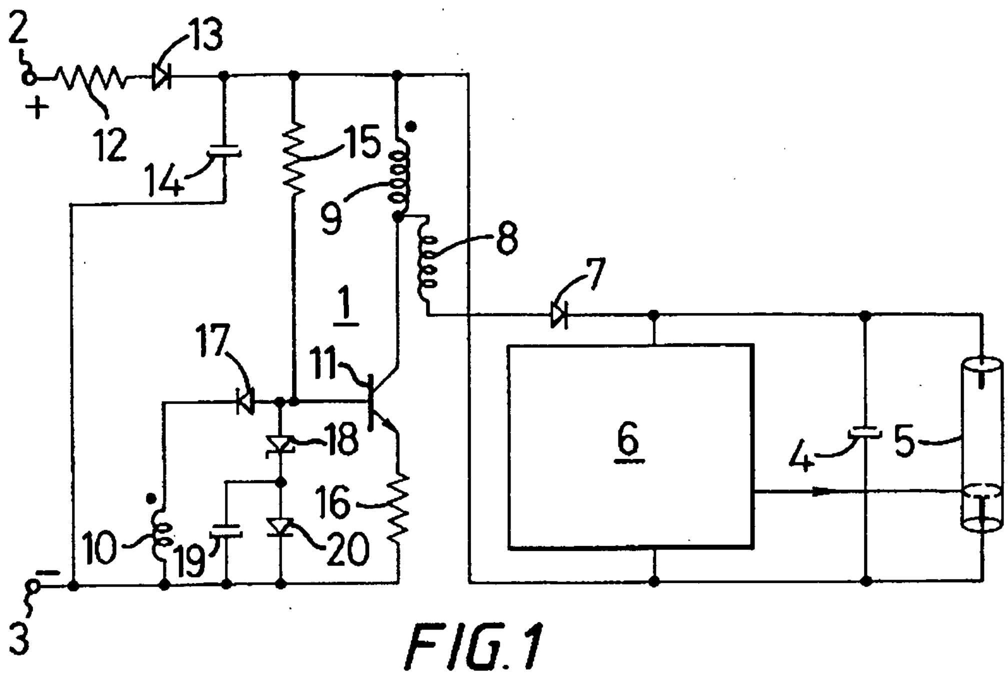

FIG.1

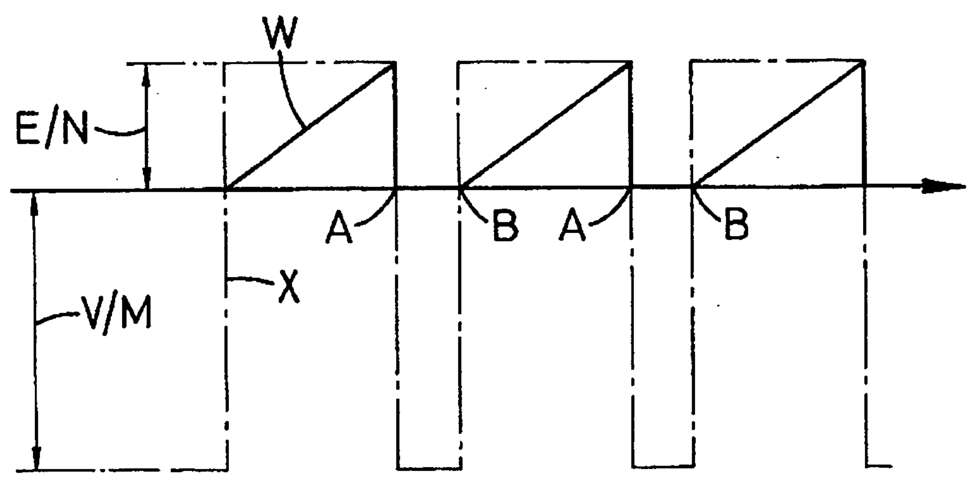

FIG.2

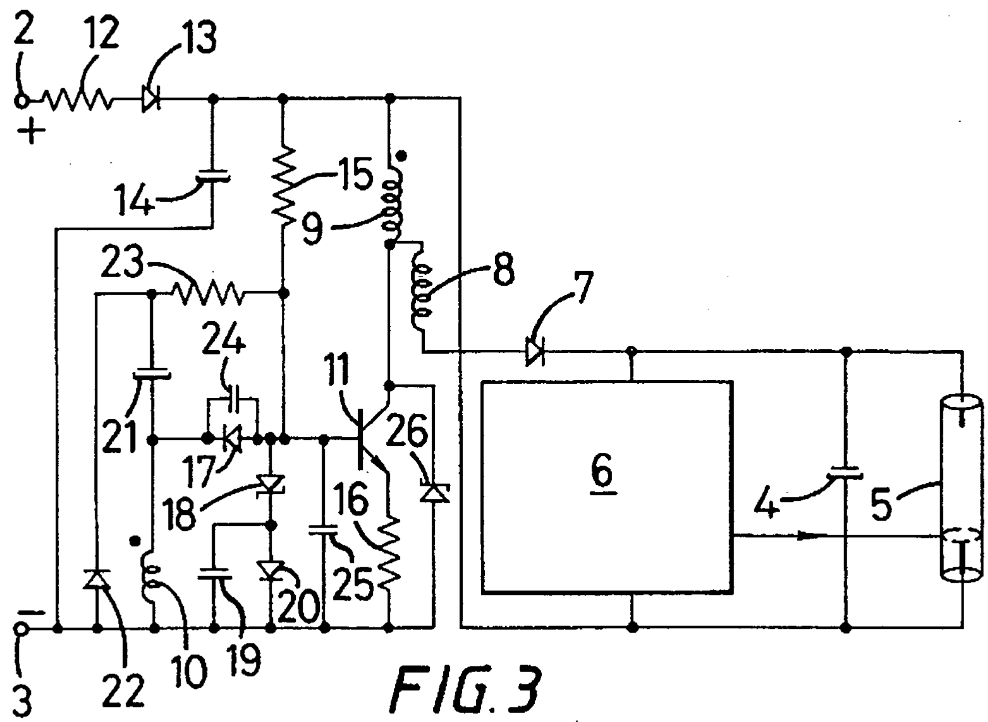

FIG. 3

INTERNATIONAL SEARCH REPORT

International Application No
PCT/GB 97/02933

A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 H05B41/34 H02M3/338

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 6 H05B H02M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 34 20 033 A (HIRSCHMANN RADIOTECHNIK) 5 December 1985 see the whole document ---	1-4
A	US 4 737 898 A (BANFALVI STEPHEN S) 12 April 1988 see the whole document ---	1-12
A	US 5 485 361 A (SOKAL NATHAN O) 16 January 1996 see abstract; figure 3 -----	1

☐ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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1

Date of the actual completion of the international search	Date of mailing of the international search report
17 February 1998	24/02/1998

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/GB 97/02933

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
DE 3420033 A	05-12-85	NONE	
US 4737898 A	12-04-88	NONE	
US 5485361 A	16-01-96	NONE	